PB86-222932

Hazardous Dust Control

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Jul 86

U.S. Department of Commerce
National Technical Information Service

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. R
EPA/600/D-86/153		PB86-222932

4. TITLE AND SUBTITLE	5. REPORT DATE
Hazardous Dust Control	July 1986
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Norman Plaks	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
See Block 12.	11. CONTRACT/GRANT NO.
	NA (Inhouse)
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
EPA, Office of Research and Development Air and Energy Engineering Research Laboratory Research Triangle Park, NC 27711	Published paper; 6/86
	14. SPONSORING AGENCY CODE
	EPA/600/13

15. SUPPLEMENTARY NOTES AEERL project officer is Norman Plaks, Mail Drop 61, 919/541-3084. Presented at Symposium on Hazardous Dust and Materials, Japan Institute of Electrostatics, Tokyo, Japan, June 4-5, 1986.

16. ABSTRACT The paper discusses hazardous dust control and related EPA programs. (NOTE: For purposes of this paper, hazardous particles or dusts are those whose size or chemical species cause harm to the population through deposition in the lungs and other portions of the pulmonary tract.) A few pollutants, some of which are particles, have been designated under the program from the Clean Air Act for National Emissions Standards for Hazardous Air Pollutants (NESHAP); more are being considered for NESHAP. Several research and development needs are listed including: sensing of excess emission of hazardous dust from control equipment; need to retrofit for improved capture of small particles; improved collection of fine condensable aerosols; and modeling of control technology for hazardous particles. Indoor air particles and dusts are discussed with emphasis on characterization, indoor air cleaners, and asbestos in residences. Radon in the indoor environment is discussed as an emerging problem. Finally, an indoor air/radon model is discussed linking indoor air dusts to lung deposition.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution Dust Control Toxicity Particles Aerosols Asbestos Atmospheric Contamination Control Radon Mathematical Models	Pollution Control Stationary Sources Hazardous Particles Indoor Air	13B 05E 06K 06T 07B 14G 12A 07D 11E

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release to Public	Unclassified	23
	20. SECURITY CLASS (This page)	22. PRICE
	Unclassified	$9.95

EPA Form 2220-1 (9-73)

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

EPA/600/D-86/153
July 1986

HAZARDOUS DUST CONTROL

By: Norman Plaks
Air and Energy Engineering Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

ABSTRACT

Hazardous particles or dusts, for purposes of this paper, are considered to be those whose size or chemical species cause harm to the population through deposition in the lungs and other portions of the pulmonary tract. A small number of pollutants, some of which are particles, have been designated under the program from the Clean Air Act for National Emissions Standards for Hazardous Air Pollutants (NESHAP); a larger number are being considered for NESHAP. Several R&D needs are listed including: sensing of excess emission of hazardous dust from control equipment; need to retrofit for improved capture of small particles; improved collection of fine condensable aerosols; and modeling of control technology for hazardous particles. Indoor air particles and dusts are discussed with emphasis on characterization, indoor air cleaners, and asbestos in residences. Radon in the indoor environment is discussed as an emerging problem. Finally, an indoor air/radon model is discussed linking indoor air dusts to lung deposition.

HAZARDOUS DUST CONTROL

There is increasing concern developing over what are termed hazardous air pollutants and their adverse effect on human health. Hazardous air pollutants, like other air pollutants, are in one of two forms--gases or particles. This paper will concern itself with hazardous particles or dusts, especially those whose size or chemical nature cause harm to humans through deposition in the lungs and other portions of the pulmonary tract.

This paper will discuss a number of issues related to hazardous air particles or dusts that have emerged or are starting to emerge in the United States. The paper will discuss how EPA's R&D is responding to these issues. It is hoped that this Symposium and the discussions that will result from it will help identify the problems and define the solutions.

In the United States, the basis for regulating particulate matter or dusts on the federal level is the Clean Air Act, as amended in August 1977. Section 109 of the Clean Air Act requires that criteria be established, based upon existing health effects data, for various pollutants. From these criteria maximum levels of ambient air loadings of these pollutants were recommended. These were called National Ambient Air Quality Standards (NAAQS). The pollutants for which this was done are:

-Particulate matter
-Sulfur dioxide
-Oxides of nitrogen
-Volatile organic compounds
-Carbon monoxide
-Lead

For the criteria pollutants, Section 110 of the Clean Air Act requires that the NAAQS be translated, by each of the States, into a plan whereby specific levels of control would be implemented for the emission sources within each state. These are called State Implementation Plans (SIPs).

Section 112 of the Clean Air Act specifically addresses hazardous air pollutants. It does not limit itself to the narrow definition chosen for this paper which relates size distribution and chemical species to human lung deposition and damage. Under this section, following a prescribed procedure, a National Emissions Standard for Hazardous Air Pollutant (NESHAP) is promulgated for various pollutants which describes the level of control that is needed. To date NESHAPs have been promulgated for the following pollutants, some of which are particulate matter or dusts:

-Mercury
-Beryllium
-Asbestos
-Vinyl chloride
-Benzene
-Radionuclides

In addition, NESHAPs have been proposed for:

-Coke oven emissions
-Arsenic

The "intent to list" has been published for a number of pollutants including:

-Chromium
-Cadmium
-Carbon tetrachloride
-Ethylene oxide
-Chloroform
-Ethylene dichloride
-1, 3-Butadiene
-Methylene Chloride
-Perchloroethylene
-Trichloroethylene

In addition to the above pollutants, a large number of others are being studied as the basis for ultimately being included as a NESHAP.

The control of particulate matter as a criteria pollutant, which results from the NAAQS and the resulting SIPs, goes a long way toward helping control hazardous air particles. The standards are for total suspended particles in the atmosphere which, as a consequence, includes both innocuous as well as hazardous particles. If total suspended particulates are decreased then so will the hazardous dusts that are included. In addition, there is evidence that suggests that some of the hazardous organics, which are listed, condense upon the dusts--especially the fine fraction.

GENERAL HAZARDOUS AIR PARTICLE RESEARCH NEEDS

There are some emerging concerns in the areas of hazardous and criteria particles that are starting to be considered in EPA's particle research program.

One important research need is to improve methods for detecting excess emissions of hazardous dusts from malfunctioning particulate matter control equipment. One of the most important methods used in field inspections is observation of the opacity of the discharge from a particle control device. If the particle control device is operating satisfactorily the emissions will have little or no opacity. For hazardous particle emissions it is likely that the emissions would have to be controlled to a very low level; perhaps to a point far below that at which the plume would become visible. Increases in emissions which would not cause an increase in opacity, but would be unacceptable from a hazardous emissions standpoint, would not be detected. A low-cost continuous sensor that would detect small increases in emissions would be useful. An example would be for control of asbestos fibers. For some applications a HEPA (high efficiency particulate air) filter might be used. A small amount of damage to the filter would allow a quantity of asbestos fibers to pass through undetected. The continuous sensor would activate an alarm so that corrective action could be taken.

A second area of research concern is the forthcoming modification to the NAAQS for particulate matter. The intent is to modify the standard so

that it will concern itself only with the finer fraction that enters the pulmonary tract and lung, where it can cause harm to humans, rather than the current total suspended particulate standard.

Early in 1978, EPA began an inhalable particulate (IP) emission characterization program for determining emission factors based on cutoff size for IPs from both controlled and uncontrolled sources. At the time, the Agency was examining the effects of several particle size fractions including: IP matter, then defined as $\leq$ 15 μm aerodynamic equivalent diameter; fine particulate, $\leq$ 2.5 μm aerodynamic equivalent diameter; and fractions between these size points. A sizeable effort was devoted during the early part of the IP characterization program to develop hardware and techniques for measurement of IP emissions from both point sources and fugitive emission sources. The particle size fraction now used by EPA for inhalable particles is $\leq$ 10 μm aerodynamic equivalent diameter. This size cut is referred to as PM_{10}.

When the IP program was initiated, it was estimated that a program designed to do a thorough characterization of all sources of IP emissions would cost $50 million. Available funds were about $4 million, so a priority list of major sources for testing was developed. The final list of high priority sources selected for characterization is:

1. Paved Roads
2. Industrial and Unpaved Roads
3. Iron and Steel
4. Ferroalloy
5. Cement and Lime
6. Primary and Secondary Nonferrous
7. Iron Foundries
8. Asphaltic Concrete
9. Kraft Pulp Mills
10. Combustion
11. Metallurgical Coke

Field tests were conducted in each of these categories, and a Source Category Report is being prepared for each. These reports used data from the IP Characterization Program tests along with all other available test data to develop PM_{10} and other size specific emission factors up to 15 μm. The source category reports are due to be completed by the fall of 1986. These emission factors are needed by the states so they can develop new SIPs for achieving the new PM_{10} NAAQS scheduled for early 1987. As proposed the new PM_{10} NAAQS is presented in Table 1. The proposed standard was presented as a range.[1] The standard when it is promulgated will be for a specific value within the range.

It is expected that, because of health concerns, the PM_{10} NAAQS will be promulgated with the primary annual standard set at the low end of the range. If this occurs, our analysis in R&D suggests that much of the existing particle control equipment will have to be upgraded to allow more effective capture of the particles $\leq$ 10 μm in size. Of special importance will be the fraction < 1 μm which is especially difficult to capture in particle control devices such as ESPs.

A third research concern is that of condensable aerosols which form outside the stack. Condensation aerosols are most often submicron in size; they could be either inorganic or organic, toxic or innocuous. In the submicron range they easily enter the pulmonary tract and lung; condensation upon other particles also occurs. Arsenic trioxide is an example of a hazardous, inorganic, condensable aerosol emitted by an industry such as copper smelting when arsenic is present in the ore. Arsenic trioxide sublimes at 193°C. If the ESP is operated at a temperature higher than 193°C, the arsenic trioxide will pass right through and will condense in the plume. Even if the ESP is operated below the sublimation temperature the condensation and coagulation aerosol that is formed will likely be in the 0.1 to 0.5 μm range--a size not easily captured in an ESP.

Table 1. PM_{10} STANDARD

	Present Total Suspended Particulate, mg/m^3	Proposed PM_{10} Standard, mg/m^3
Primary - Annual	75	50 to 65
Primary - 24 hr	260	150 to 250
Secondary - Annual	None	70 to 90 (TSP)
Secondary - 24 hr	150	None

Another research concern is how to provide design certainty for the proper sizing of control equipment for the collection of hazardous air pollutant particles and dust, especially ESPs. A great deal of work has been done on developing computer models for ESPs by EPA and Southern Research Institute.[2] These models have been very well verified for collection of flyash from the combustion of coal. There is very little verification for collection of industrial dusts. What is needed is good data on the collection efficiency, the particle size distribution, the particle resistivity either in situ or in the laboratory, and the ESP electrical conditions. Of course the ESP must be in good mechanical condition. With enough data sets the ESP models could be verified for a number of hazardous air dusts.

INDOOR AIR CLEANERS

There is an increased awareness of the generally poor quality of indoor air. Emphasis in research activities has centered primarily on the volatile organic materials that are commonly used in modern construction. With the recognition of the role of tobacco smoke and the increasing number of homes in which radon is being found, there has been a new effort to look at particle removal from indoor air. Work in indoor air and radon is not being done under the Clean Air Act. It is currently being funded by means of separate congressional appropriations.

Central air cleaning units in indoor air heating, ventilation, and air conditioning system are used to remove dust and particles circulated through the system. Particle removal in these units is based on principles of filtration and electrostatic precipitation. At the current time there is not a standardized testing methodology for evaluating the performance of these units. The organization most active in promoting indoor air studies, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), has become keenly interested to the point of forming a standing committee for indoor particulate. In EPA a program is now underway to study the problem of how to evaluate indoor air cleaners. The

objective is to develop a vigorous repeatable procedure and to demonstrate the procedure on selected devices. Of special importance in the tests will be the evaluation of fractional efficiency and the determination of revolatilization of materials condensed upon particulate matter or collecting surfaces. The program consists of:

- The design and construction of a test stand for evaluation of selected air cleaners.
- The development of a standard aerosol that will represent dust found in residences.
- The evaluation of a number of state-of-the-art central air cleaners as a function of total and fractional efficiency, and of revolatilization of condensed matter.

If improved effectiveness is needed, recommendations will be made on what changes should be incorporated into the air cleaner design.

CHARACTERIZATION OF INDOOR AIR

As part of the indoor air particle control program, work is underway to characterize the dusts found in the indoor air environment. This work has started with a series of tests in an office building in the Research Triangle Park area of North Carolina.[3] The offices have a circulating ventilation system. Outdoor air, whose particle content was always lower than that of the indoor air, was combined with the circulating indoor air in varying proportions, by means of a damper. Filter test results showed an average collection efficiency of 15-20% for submicron particles. The tests were conducted over a 5-day period. For 2 of the days the outdoor air dampers were closed, and for 2 of the days the dampers were open. The last test each day was done in a building that was unoccupied; the outdoor air damper was closed.

Figure 1 shows a plot of the particle mass concentration for the various rooms in the building. The position of the symbols indicates the room number; the same rooms were not necessarily sampled in each day's tests. The mass concentration is increased with occupancy. The mass

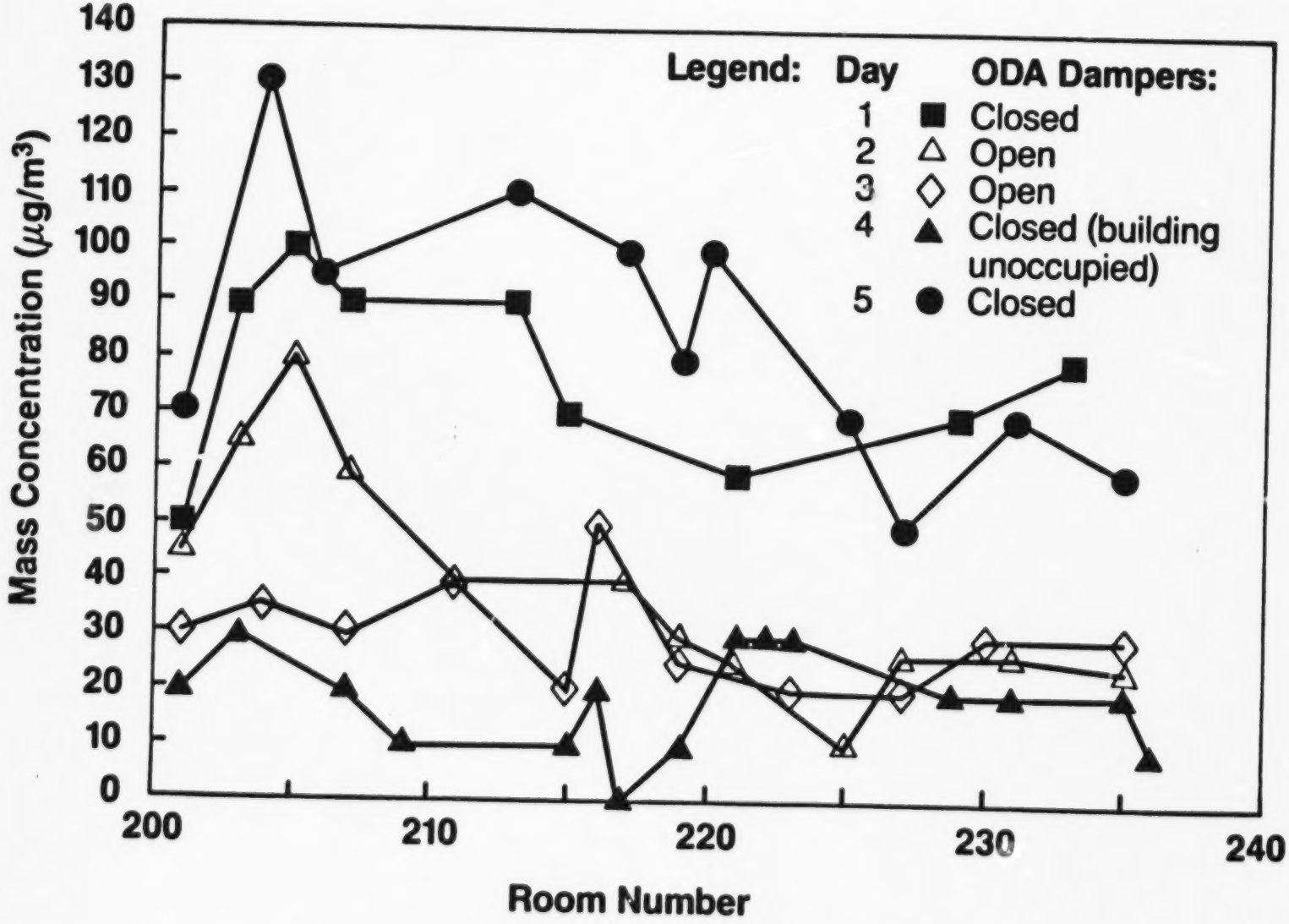

Figure 1. Indoor Air Office Building Daily Particle Mass Concentration Profile.

concentration decreases when the outdoor air (ODA) dampers are opened. The influence of occupancy is emphasized by the fact that the concentrations when unoccupied were low or lower using 0% ODA than those when the building was occupied or using 100% ODA.

Figure 2 shows how smokers were distributed among the various rooms. A comparison of figures indicates that in general, the higher mass concentrations were found near the higher smoker concentrations. Details of smokers' presence, movement, or rate of smoking were beyond the scope of this project; therefore, no firm conclusion can be reached concerning their influence.

Figures 3 and 4 show the normalized particle number and volume distribution, respectively. These tests were made for the supply air to the rooms with the ODA damper closed. The number of particles peaked at 0.13 μm, and the volumetric distribution peaked at 0.3 μm; both are in the respirable range. The results were similar for the return air duct and for the ODA damper open. The instrumentation referred to in the legend was a differential mobility particle size or (DMPS) and laser spectroscopy (LAS-X).

ASBESTOS IN RESIDENCES

In the period 1920 to 1970 asbestos was used in residences for a number of purposes. Included was use in piping, furnaces, electrical insulation, plastering of walls, floor and ceiling tile, wall coatings, roofing, and siding. There is concern about asbestos fibers from these uses getting into the indoor environment and ultimately causing harm to the occupants. Because asbestos is a well known cause of several types of cancer, there is significant potential concern. For example, asbestos-containing heating ducts were installed in 100,000 homes in Orange County, California, alone.[4] Extrapolating this to the whole country indicates the extent of the potential problem.

To answer the question of whether or not there is an asbestos problem in residences, as a result of airborne fibers, a study has been started. A cross section of homes, in which asbestos (in its many forms) has been used, will be surveyed and sampled by EPA. Taken into consideration will be the age, state of repairs, number of occupants, etc. A routine will be set up for collecting samples of air, dust, and the materials of construction.

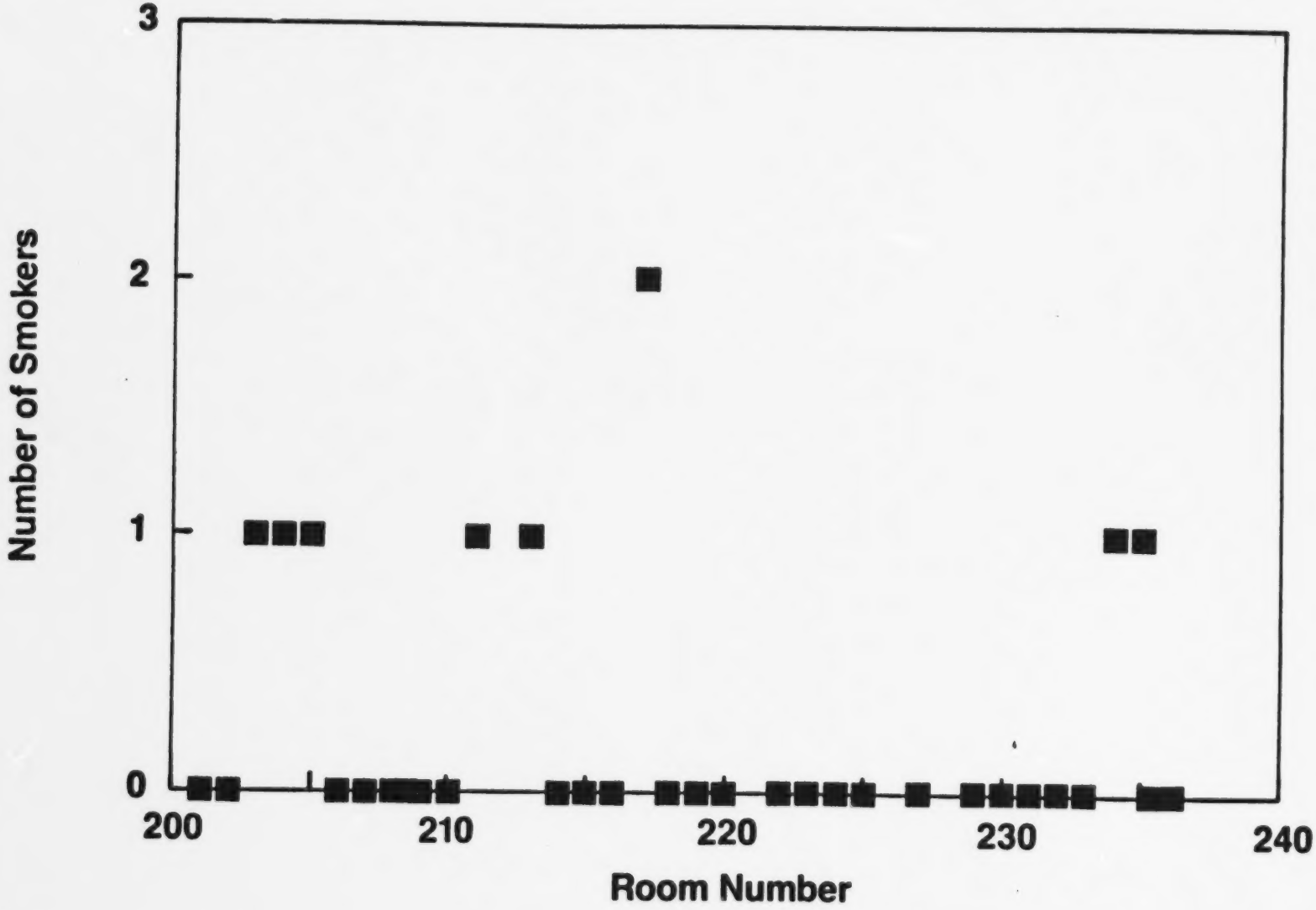

Figure 2. Indoor Air Office Building Smoker Distribution.

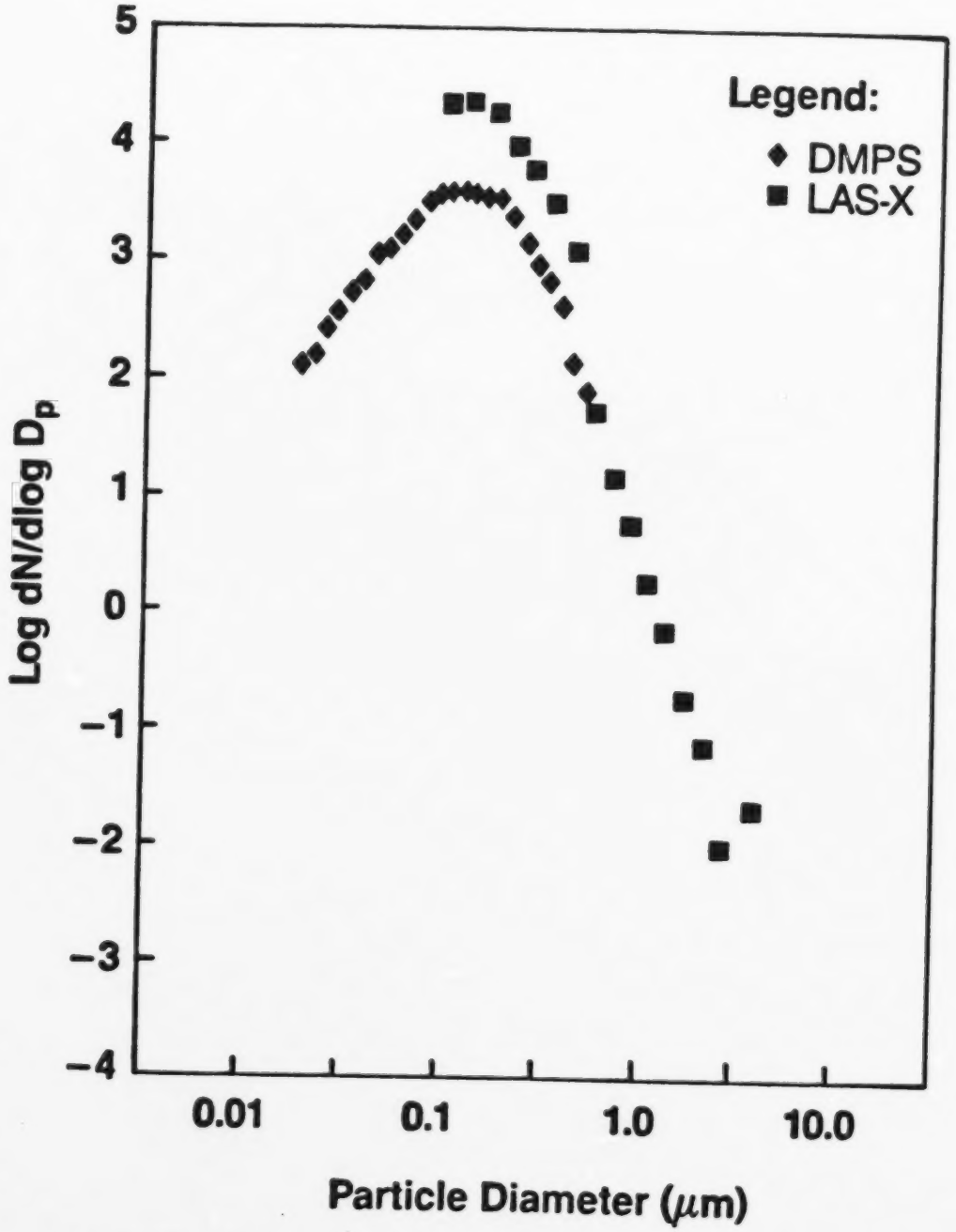

Figure 3. Indoor Air Office Building Particle Number Distribution.

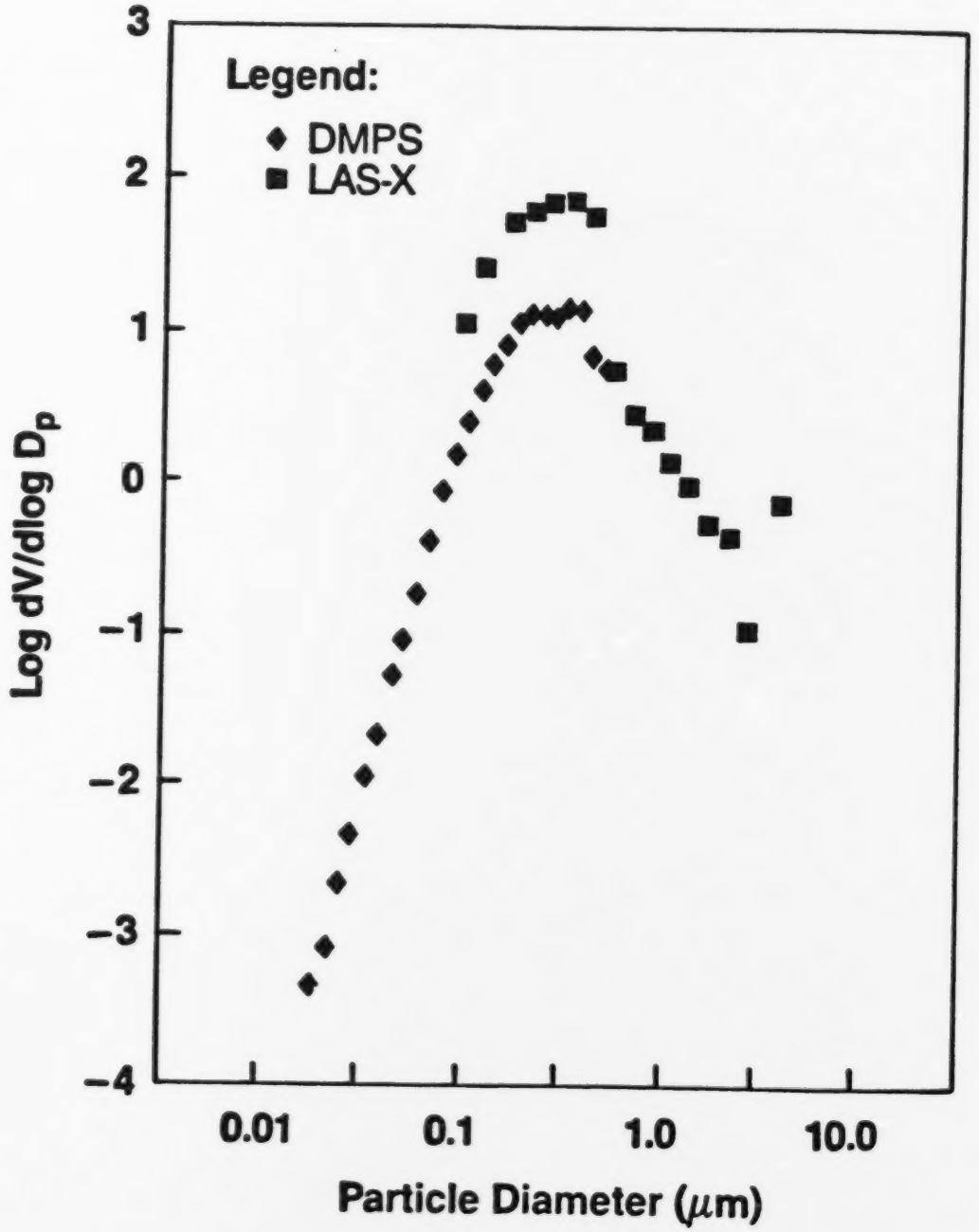

Figure 4. Indoor Air Office Building Particle Volume Distribution.

If asbestos fibers are found in the indoor environment it may become necessary to start up a program to mitigate the problem. Possible mitigation techniques might include replacement of material, use of a fixing agent to retain asbestos fibers in place, or improving air cleaning techniques. If replacement of materials containing the asbestos or sealing the fibers in place is called for, special practical procedures for home owners will have to be developed. Even if materials can be left in place, it may be necessary to develop procedures for remodeling older homes without disturbing the asbestos. The study should reveal the extent of precautions necessary under these circumstances.

RADON

A recently emerging problem gaining national prominence is radon infiltration into homes. Concern and mitigation activities have also started in Canada, Scandinavia, Eastern Europe, and other countries. Noble gas radon is a decay product of the chain that starts with uranium -238 and ends with the stable product, lead-206.

Of specific concern is that portion of the chain that starts with Radon-222 and ends with lead-210 (Figure 5). The four decay byproducts--polonium-218, lead-214, bismuth-214, and polonium-214, are sometimes called "radon daughters." These radon daughters, when they decay, emit alpha, beta, and gamma radiation. Of these, the alpha particle is considered to be the most biologically harmful of the three. The radon daughters have half lives that are of the same order as is the time that they would be in the indoor air environment and could be deposited in the occupants' lungs where the alpha particles would cause long term harm.

Radon gas most commonly enters homes by diffusion from the soil through cracks and otner openings in the foundation and structure. The most effective method for mitigating the radon problem is to prevent its entry.[5] This has been done on some homes by applying suction to the soil, close to the points where the radon would enter, to lower the soil gas pressure; the output of the suction pump or blower is discharged to the outside air. In other homes hollow foundation walls have been evacuated by suction which diverts the radon before it can enter the home. Other techniques call for dilution of the inside air with outside air to lower the radon level. Dilution with outside air requires the use of air-to-air

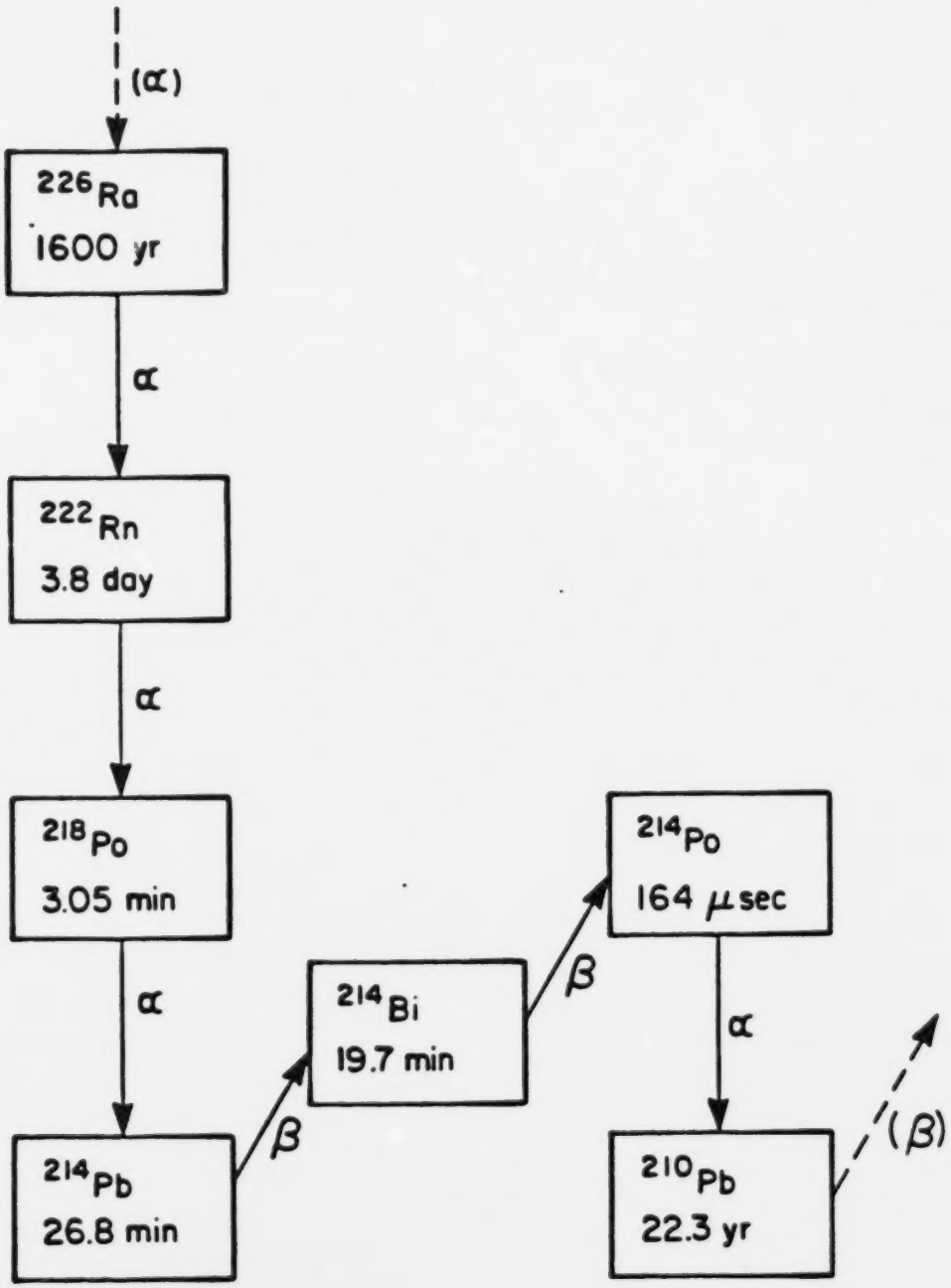

Figure 5. Radium, Radon Decay Chain (^{238}U Decay Series).

heat exchanges to conserve energy. These approaches--suction and evacuation to minimize entry of the radon and dilution--are useful where it is technically and economically feasible. It is especially useful where the working level (WL) in the homes is especially high and must be reduced significantly. A WL is defined as any combination of the short-lived radon daughters per liter of air whose decay will result in the ultimate emission of 1.3×10^5 million electron volts (MeV) of potential alpha energy. One WL is also equivalent to the alpha-emitting potential of radon daughters in radioactive equilibrium with 100 pCi (picocuries) of radon per liter of air.

For those cases where it is not technically or economically feasible to prevent or sufficiently decrease the entry of radon gas into a home, it may be necessary to use other mitigation methods. Consequently, consideration has to be given to dust and particle removal by gas cleaning.

The radon daughters are actually particles, rather than a gas, and consequently obey the rules of aerosol physics. They coagulate with other dust particles to form larger particles. Initially they coalesce to form somewhat larger particles in the range of about 0.002 to 0.02 μm. They plate out onto walls and other surfaces. Much of their behavior results from the charge, which these particles contain, and which enhances their coalescing and plating out. Those that do not plate out or remain unattached grow to the size range of about 0.2 to 0.5 μm which is the most difficult range to capture by ordinary particle collection devices.

For homes in which it may not be feasible for radon to be mitigated, it is the deposition of the radon daughter particles within human lungs that is of concern. According to some estimates the inhalation of radon decay products may be responsible for as much as 10% of the incidence of lung cancer in the United States.[6,7]

As previously indicated the radon daughters tend to coagulate with other particles or dust in the indoor environment. The greater the number of dust particles in the air the greater are the number of radon daughters that attach themselves. On the other hand the fewer particles in the air the more unattached radon daughters there are. There is concern among many experts that unattached radon daughters, because of

their higher mobility, are more hazardous than are the attached ones. There is debate underway on whether or not it is desirable to remove more of the dust particles from the air by improved air cleaning.

INDOOR AIR AND RADON MODEL

We have discussed a number of activities related to indoor air including its characterization, the effects of changes in the quantity of indoor pollutants (such as cigarettes), infiltration of radon, air exchange with outside air, and air cleaning. The critical questions include: how are all these variables handled? and what are the interactions? Another useful question would be: what might be the effect on human health of various strategies for changing the variables? To answer these questions a computerized model is being developed. The inputs and outputs of the model are shown in Figure 6.

The indoor air/radon model is being developed to provide an integrated method of assessing the best available information on the risks associated with various forms of indoor air pollution and radon. The model will be designed to deal with both steady state and time dependent situations. The steady state predictions will be useful for assessing the risks associated with long term exposure to pollutants such as radon, while the time dependent predictions will be useful for assessing the risks associated with short term exposures such as might occur with accidental releases of hazardous materials.

The model will incorporate as modules the best available models and data in developing predictions of such parameters as air infiltration, air ventilation in rooms, performance of air cleaning equipment, particle coagulation, deposition of particles and other pollutants in the lungs, and risk due to various exposure patterns. The model will also consider the costs associated with various actions, such as air cleaning and the effects of actions on comfort.

A first phase version of the model has been developed to prove the feasibility of the concept and to identify important areas that must be included in the final version of the model. This first phase version of the model is based on a simple perfect mixing ventilation system. The

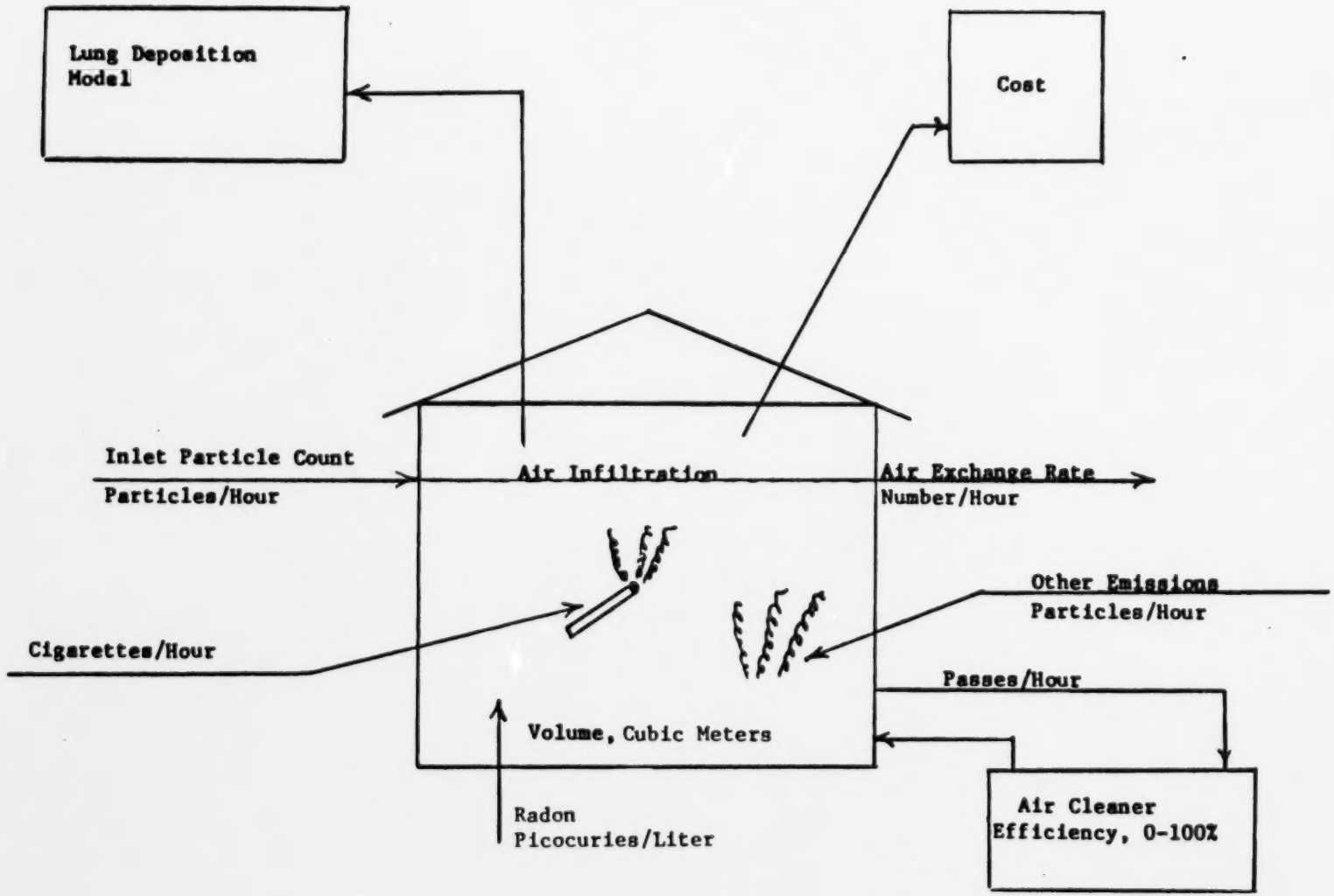

Figure 6. Indoor Air/Radon Model.

first phase model is designed to allow analysis of the steady state situation and especially to study the effects of air cleaning equipment on dangers due to radon and radon daughters.

The model assumes that there are two different sized particles present--0.001 μm diameter fine particles and 2 μm normal particles. The fine particles, usually unattached radon daughters, are removed from the room air by coagulation with tne large particles, impaction on the room walls, and capture in the air cleaning equipment. The large particles are removed by fallout and capture by air cleaning equipment. The indoor air large particle concentration is also affected by infiltration of outside air, particle generation in the room, and smoking. The concentration of fine radon particles is affected by infiltration of radon gas, the removal processes discussed above, radioactive decay of the daughters, and dilution with outside air.

The model is able to calculate the steady state concentration of radon gas (or other infiltrating gas), the steady state concentration of fine unattached radon daughter particles, the concentration of large particles, and the amount of alpha radiation potential attached to them. The model uses a simple three zone lung deposition module to calculate the particle and alpha radiation potential deposition in each of the three respiratory zones.

The model allows qualitative analysis of the effects of air cleaner efficiency and ventilation rate on the various particle concentrations. These effects can then be coupled with the lung deposition module to allow assessment of the effect of various cleaning options on the lung deposition patterns. The model also makes it possible to assess the effects of smoking, infiltration rates, and radon gas levels on the lung deposition patterns.

Future work will involve improving the particle size resolution of the model by incorporating an improved coagulation module and data on the particle size distribution of smoke and general indoor air particulate. Work will also be done to improve the mixing module to incorporate work done on indoor ventilation and mixing patterns. The current lung deposition module will be improved by using a state-of-the-art model. Time dependency will be added to the model as will a cost module and a risk assessment module.

REFERENCES

1. Federal Register. "Regulations for Implementation Revised Particulate Standards; Proposed Rule," Vol. 50, No. 63, Tuesday, April 2, 1985.

2. Faulkner, M.G., and DuBard, J. L., "A Mathematical Model of Electrostatic Precipitation (Revision 3)," Vols. I and II, EPA-600/7-84-069a and b, (NTIS PB 84-212 679 and -212 687), June 1984.

3. Owen, M. K., Ensor, D. S., Hovis, L. S., and Tucker, W. G., "Effects of Office Building and Ventilation System Parameters on Respirable Particles," Presented in Poster Session at the ASHRAE IAQ '86 Conference, Atlanta, GA, April 1986.

4. Lausen, G., "Is Your Dream House a Nightmare," American Health, Vol. 5, No. 5., June 1986, p. 82.

5. Henschel, D.B., and Scott, A.G., "The EPA Program to Demonstrate Mitigation Measures for Indoor Radon: Initial Results," APCA International Specialty Conference on Indoor Radon, Philadelphia, PA, February 1986.

6. Letter from D. Hawkins, Assistant Administrator for Air, Noise and Radiation, U.S. Environmental Protection Agency, to M. Savitz, Assistant Secretary for Conservation and Solar Applications, U.S. Department of Energy, 1979.

7. Budnitz, R. J., Berk, J. V., Hollowell, C.D., Nazaroff, W. W., Nero, A.V., and Rosenfeld, A. H. (1978). Human Disease from Exposure: The Impact of Energy Conservation in Buildings. Lawrence Berkeley Laboratory Publication No. 7809, University of California, Berkeley, CA.

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.